

Phytotoxicology Investigation in the Vicinity of Algoma Steel Inc. Sault Ste. Marie - 2005

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Background

Algoma Steel Incorporated is an integrated primary iron and steel producer located on the St. Mary's River in Sault Ste. Marie, Ontario. Integrated mills produce steel in blast furnaces where iron ore is mixed with coke and the coke is burned under controlled conditions so that carbon monoxide is produced. This carbon monoxide chemically reduces the ore, consisting primarily of iron oxides, to metallic iron. Limestone added to the furnace provides an additional source of carbon monoxide as well as acting as a flux to fuse with silicates in the ore. The resulting calcium silicate floats to the top of the molten iron and is drawn off as slag.

A critical material in steel making is the coke. Coke is produced by heating coal to high temperatures and distilling off the volatile components of the coal. The remaining material consists primarily of carbon and is known as coke. Coke provides the high heating value to smelt the iron ore and is also the source of carbon in steel.

Integrated mills produce their own coke in coke ovens. The ovens consist of narrow vertical chambers known as 'batteries'. The heat to distill the coal is generated by burning gases in spaces between adjoining chambers. Volatile compounds released as the coal is distilled are condensed to produce coal tar, while the non-condensed gases are recovered and burned to distill fresh charges of coal.

Polycyclic Aromatic Hydrocarbons

During coke production there are inevitable emissions of volatilized coal tar or of coal gas to the atmosphere. Major constituents of coke oven emissions are a class of organic compounds known as polycyclic aromatic hydrocarbons (PAHs). PAHs consist of three or more fused aromatic rings. Some consist only of carbon and hydrogen atoms, while some PAHs have other atoms substituting for carbon in the benzene ring, or functional groups substituting for hydrogen atoms. Consequently, it is possible to have a great diversity of PAHs. It should be noted that PAHs are not necessarily constituents of coal but can be formed during the coal distillation process.

The boiling points of PAHs are usually high enough so that they will not persist in the atmosphere in vapour form, but will condense onto particulates acting as condensation nuclei. Consequently, the dispersion and deposition characteristics of PAHs are dependant on the behaviour of the particulate nuclei. Small particles will be transported greater distances than larger particles and can theoretically contain a higher mass to volume ratio of adsorbed PAHs. However, since the greater the dispersion distance, the greater the dilution, ambient air concentrations of PAHs, either in vapour or particulate form, are invariably higher near a point source.

The primary concern about PAHs is that some are considered probable human carcinogens. One of these, benzo(a)pyrene, has been the subject of considerable toxicological research and is the only PAH compound for which Ontario has an ambient air standard. The benzo(a)pyrene ambient air standard of 1.1 nanograms per cubic metre of outdoor ambient air per 24 hours is regularly exceeded at a MOE monitoring station located near a residential neighbourhood near and to the northwest of the Algoma Steel complex.

Investigation Design

The investigation which is the subject of this report follows previous investigations conducted in 1998 and 2003. These investigations were reported in MOE Phytotoxicology reports SDB-075-3511-1999 and Phyto-S5020-2003.

The 1998 investigation concluded that Algoma Steel was a source of airborne PAHs, but that the soil sampling site distribution was too wide and that there were an inadequate number of sites in the adjacent residential neighbourhood to adequately assess the effect of PAH emissions from Algoma Steel on the soil of that neighbourhood. There were three soil sampling sites in the neighbourhood adjacent to the northwest of Algoma Steel and 17 more between one and four kilometres from the coke ovens.

The 2002 investigation focussed only on the neighbourhood adjacent to the northwest of Algoma Steel. Twenty new sampling sites were established, primarily on lawns of residential properties. Soil from the near surface (0 to 2.5 centimetres) was collected at these sites. This investigation determined that soil PAH concentrations were indeed elevated and that Algoma Steel was the source. However, the soil PAH concentrations but did not exceed health-based criteria.

For 2005 the MOE Sault Ste. Marie District Office requested that the Phytotoxicology Investigations Unit (PIU) expand the investigation to more definitively determine whether the PAH emissions and resultant air concentrations were resulting in soil contamination that could be a concern to the health of residents in this neighbourhood.

The investigation was conducted on August 9 and 10, 2005. The locations sampled in 2002 were re-sampled in the same manner. Ten additional locations were added, concentrating in the part of the neighbourhood that was closest to the coke oven batteries of Algoma Steel.

After the surface sampling at the 30 locations was completed, three were re-visited to determine whether the soil in this neighbourhood exhibited a PAH concentration gradient with depth. To accomplish this, soil samples were collected at four depth increments of five centimetres each to a depth of 20 centimetres.

A fourth location was also sampled in five centimetre increments to a depth of 20 centimetres. This location was not in the subject neighbourhood. It was a location sampled in 1998 when the wider geographic area was addressed. This location was distinguished with much higher PAH concentrations than all other 1998 locations.

In addition to sampling soil, three Norway maple trees were selected for foliage sampling. This was one more attempt to use tree foliage as an indicator of the relative magnitude of PAHs in the air in the vicinity of the coke ovens. The foliage samples were collected in the mid-afternoon on August 9, 2005, immediately before a major thunderstorm. This provided an opportunity to sample again the following day in an attempt to establish how significant rain can be in washing accumulated particulates from foliage surfaces.

Figure 1 consists of an orthorectified image of the investigation area captured during an air photography survey in 2004. Sampling locations for the soil and tree foliage samples have been added to this image.

Figure 1: Soil Sampling Locations - Algoma Steel Inc., Sault Ste. Marie - 2005

Sampling Procedures

Prior to sampling, all sampling equipment that would be in contact with the soil sample was washed with a high-phosphate detergent, rinsed with de-mineralized water, and then successively rinsed with acetone and hexane. The sample containers were amber glass jars with Teflon™ lids. These containers were previously washed with a detergent solution followed by several de-ionized water rinses and were provided by the MOE Laboratory Services Branch.

A sampling location for the surface soil samples consisted of the whole of the sodded portion of the yard, or an area about 10 metres by 10 metres if the yard was particularly large.

Ten cores of soil to a depth of 2.5 centimetres were removed over a grid pattern with a soil coring device consisting of a hollow, two centimetre diameter, stainless steel tube fitted with a cutting tip. The individual cores were placed into a stainless steel bowl, homogenized and transferred to a labelled glass sample jar.

The soil profile sampling used the same equipment but the corer was inserted to depth of at least 20 centimetres. The extracted soil core was sectioned into the four increments of five centimetres each and placed into the jars. Five cores were collected and each increment class was placed into a common jar. The jars were shaken vigorously to homogenize the samples.

Tree foliage samples were collected by cutting a branch from a portion of the canopy that was well exposed to the Algoma Steel coke ovens. The leaves from the branch were removed by hand while wearing neoprene gloves and placed into an amber glass jar.

All samples were forwarded to the MOE Laboratory Services Branch for determination of PAH concentrations by gas chromatography - mass spectrometry (GC-MS). The analytical method applied to the 2005 soil samples differed from previous methods. The analysis included spiking of the samples with deuterium-labelled PAH compounds and determining the proportion of the spikes recovered during the concentration determination. This recovery value was used to correct the apparent concentrations of the target PAH compounds. This methodology is more precise and expands the list of PAHs that are quantified by two for a total of 18 PAH compounds.

The analysis of the foliage samples followed older methodology, using labelled spikes of only three PAHs as a quality control to ensure that recoveries were within acceptable limits. Corrections for recovery were not applied and 16 PAH compounds are reported.

Results

Table 1 contains the concentrations of the 18 PAH compounds in the surface soil from the 30 locations collected during this investigation. The data are reported in nanograms per gram (ng/g), also known as parts per billion, on a dry weight basis. The last two columns in this table contain the concentrations from Table 1 (Full Depth Background Site Condition Standards) and Table 3 (Full Depth Generic Site Condition Standards in a Non-Potable Ground Water Condition) as contained in *O. Reg. 153/04*, the Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act. The Appendix contains information on the legislation governing standards for soil contaminants.

Table 2 contains PAH data from the three locations in the subject neighbourhood where soil was sampled to a depth of 20 centimetres, as well as the fourth location where anomalously high PAH concentrations were detected in 1998.

Table 3 reports the PAH concentrations for the foliage samples, in nanograms per gram, on a fresh weight basis. Data for samples collected before and after the rain storm are listed, as are the % differences. Reductions in PAH concentrations in tree foliage after the rain event are indicated by data in brackets. It must be recognized that before and after samples are not the same samples. However, the post rain samples came from branches that were next to those cut before the rain.

Table 1: PAHs (ng/g dw) in Surface Soil (0-2.5 cm) near Algoma Steel, SSM - 2005

Site	21	22	23	24	25	26	27	28	29	30
Naphthalene	460	280	230	180	300	240	140	200	120	170
Acenaphthylene	53	39	45	26	62	83	41	52	24	85
Acenaphthene	13	12	13	8	33	19	12	14	5	10
Fluorene	62	40	40	29	61	41	29	35	21	30
Phenanthrene	490	340	410	240	670	480	270	360	170	340
Anthracene	62	45	53	31	98	74	53	49	22	48
Fluoranthene	620	460	630	310	1,100	980	680	570	240	670
Pyrene	510	360	500	250	930	830	580	470	190	550
Benzo(a)anthracene	270	190	240	130	500	430	310	250	97	290
Chrysene	520	340	450	250	840	710	440	460	210	500
Benzo(b)fluoranthene	510	360	480	260	960	760	490	490	240	570
Benzo(k)fluoranthene	210	150	210	110	430	340	230	210	96	250
Benzo(e)pyrene	350	230	330	170	600	480	320	330	140	390
Benzo(a)pyrene	310	220	300	170	650	520	350	300	130	370
Perylene	84	59	95	51	190	160	120	88	42	120
Indeno(1,2,3-c,d)pyrene	350	250	330	280	910	690	470	450	220	560
Dibenzo(a,h)anthracene	58	44	52	31	130	82	59	58	27	66
Benzo(g,h,i)perylene	280	200	260	160	570	470	260	270	130	320

Table 1(cont.): PAHs (ng/g dw) in Surface Soil (0-2.5 cm) near Algoma Steel, SSM - 2005

Site	31	32	33	34	35	36	37	38	39	40
Naphthalene	210	320	280	160	250	190	170	170	110	210
Acenaphthylene	92	65	39	25	74	69	66	59	19	31
Acenaphthene	14	22	10	4	15	12	15	7	7	10
Fluorene	40	56	32	21	40	34	33	21	16	24
Phenanthrene	490	530	330	200	410	390	410	260	160	250
Anthracene	80	74	40	30	63	57	56	39	19	33
Fluoranthene	1,000	740	440	350	650	640	890	540	230	320
Pyrene	810	580	340	270	510	520	720	440	180	250
Benzo(a)anthracene	410	300	170	140	260	280	340	230	87	130
Chrysene	730	580	360	250	550	560	590	410	170	280
Benzo(b)fluoranthene	760	580	350	270	540	550	680	490	190	300
Benzo(k)fluoranthene	340	250	150	110	230	240	310	210	82	130
Benzo(e)pyrene	460	360	230	170	350	330	380	300	120	210
Benzo(a)pyrene	470	370	220	170	330	330	440	310	120	180
Perylene	150	110	57	48	100	91	120	100	35	68
Indeno(1,2,3-c,d)pyrene	690	520	370	260	520	510	670	510	200	340
Dibenzo(a,h)anthracene	96	68	45	32	62	64	89	58	22	38
Benzo(g,h,i)perylene	400	310	210	140	300	290	360	270	110	200

Table 1(cont.): PAHs (ng/g dw) in Surface Soil (0-2.5 cm) near Algoma Steel, SSM - 2005

Site	41	42	43	44	45	46	47	48	49	50
Naphthalene	450	420	250	260	480	230	210	170	180	200
Acenaphthylene	48	110	64	42	57	110	47	42	20	41
Acenaphthene	13	14	10	14	14	16	55	11	8	10
Fluorene	48	51	36	32	44	45	86	31	26	34
Phenanthrene	500	680	370	340	480	580	1,200	290	240	370
Anthracene	48	85	52	40	46	80	150	39	29	59
Fluoranthene	610	1,400	680	510	610	1,300	2,800	470	280	540
Pyrene	500	1,400	550	420	480	1,000	2,300	400	210	410
Benzo(a)anthracene	240	700	310	200	260	520	1,100	210	110	210
Chrysene	540	1,100	510	430	590	910	1,800	410	280	390
Benzo(b)fluoranthene	500	1,200	540	430	570	1,000	2,100	410	250	370
Benzo(k)fluoranthene	240	550	250	220	250	480	1,000	200	100	160
Benzo(e)pyrene	290	660	300	260	330	580	1,200	240	150	220
Benzo(a)pyrene	300	780	330	280	350	640	1,400	260	130	230
Perylene	77	200	88	75	89	180	420	66	29	55
Indeno(1,2,3-c,d)pyrene	420	950	450	370	560	880	1,700	400	200	330
Dibenzo(a,h)anthracene	61	150	71	54	69	120	220	45	32	43
Benzo(g,h,i)perylene	300	640	270	250	350	540	1,100	220	140	220

Table 1(cont.): PAHs (ng/g dw) in Surface Soil (0-2.5 cm) near Algoma Steel, SSM - 2005

Soil Standards*	Table 1	Table 3
Naphthalene	90	40,000
Acenaphthylene	80	100,000
Acenaphthene	70	1,000,000
Fluorene	120	350,000
Phenanthrene	690	40,000
Anthracene	160	28,000
Fluoranthene	1,100	40,000
Pyrene	1,000	250,000
Benzo(a)anthracene	740	40,000
Chrysene	690	12,000
Benzo(b)fluoranthene	470	19,000
Benzo(k)fluoranthene	480	19,000
Benzo(e)pyrene	-	-
Benzo(a)pyrene	490	1,200
Perylene	-	-
Indeno(1,2,3-c,d)pyrene	380	12,000
Dibenzo(a,h)anthracene	160	1,200
Benzo(g,h,i)perylene	680	40,000

*O. Reg. 153/04 - see Appendix

Table 2: PAHs (ng/g dw) in Soil Depth Increments near Algoma Steel, SSM - 2005

Site Depth Increment (cm)	Site 21				Site 25				Table 1*
	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20	
Naphthalene	450	410	200	170	300	380	180	110	90
Acenaphthylene	58	51	35	41	71	110	48	22	80
Acenaphthene	12	11	6.2	4.5	37	62	36	16	70
Fluorene	55	40	22	19	48	61	33	17	120
Phenanthrene	480	400	230	220	600	890	500	270	690
Anthracene	62	54	33	34	74	120	67	37	160
Fluoranthene	620	560	400	480	980	1600	920	520	1,100
Pyrene	530	500	360	430	840	1400	800	440	1,000
Benzo(a)anthracene	270	250	180	220	380	640	390	210	740
Chrysene	550	500	330	360	740	1200	700	370	690
Benzo(b)fluoranthene	510	470	320	360	730	1200	700	380	470
Benzo(k)fluoranthene	240	220	160	180	360	560	340	180	480
Benzo(e)pyrene	340	290	200	210	490	720	440	240	-
Benzo(a)pyrene	330	300	220	260	500	830	510	260	490
Perylene	99	93	69	72	140	250	130	67	-
Indeno(1,2,3-c,d)pyrene	510	380	260	320	590	1000	680	440	380
Dibenzo(a,h)anthracene	56	52	37	43	96	160	100	48	160
Benzo(g,h,i)perylene	290	270	170	190	450	700	450	230	680

*O. Reg. 153/04 - see Appendix

Table 2: PAHs (ng/g dw) in Soil Depth Increments near Algoma Steel, SSM - 2005

Site Depth Increment (cm)	Site 32				Site 20 ¹⁹⁹⁸				Table 3
	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20	
Naphthalene	300	260	210	230	160	130	120	200	40,000
Acenaphthylene	59	63	55	68	180	170	170	200	100,000
Acenaphthene	37	15	15	13	260	130	130	670	1,000,000
Fluorene	48	35	26	30	240	130	130	650	350,000
Phenanthrene	570	440	420	420	2800	1900	1800	5900	40,000
Anthracene	86	57	60	60	290	180	160	800	28,000
Fluoranthene	920	680	670	730	4200	3300	3200	8000	40,000
Pyrene	750	550	550	610	3500	2800	2600	6400	250,000
Benzo(a)anthracene	430	280	280	310	1300	1100	1000	2900	40,000
Chrysene	790	570	540	570	2400	2100	1900	4900	12,000
Benzo(b)fluoranthene	780	530	530	570	2200	1900	1900	4200	19,000
Benzo(k)fluoranthene	380	260	260	280	1100	990	950	2100	19,000
Benzo(e)pyrene	470	340	340	370	1400	1200	1200	2400	-
Benzo(a)pyrene	550	350	360	390	1600	1400	1400	3100	1,200
Perylene	170	110	100	97	450	380	370	840	-
Indeno(1,2,3-c,d)pyrene	890	590	610	660	2100	1900	2000	3400	12,000
Dibenzo(a,h)anthracene	100	67	81	83	270	240	240	510	1,200
Benzo(g,h,i)perylene	450	290	290	330	1200	1000	990	2100	40,000

*O. Reg. 153/04 - see Appendix

Table 3: PAHs (ng/g fw) in Norway Maple Foliage near Algoma Steel Before and After Rain Storm - SSM - 2005, values in brackets are % less PAHs after the rain event.

	Site 1 before	Site 1 after	Site 1 % difference	Site 2 before	Site 2 after	Site 2 % difference	Site 3 before	Site 3 after	Site 3 % difference
Naphthalene ¹	20	20	0	20	20	0	20	20	0
Acenaphthylene ¹	20	20	0	20	20	0	20	20	0
Acenaphthene ¹	20	20	0	20	20	0	20	20	0
Fluorene ¹	20	20	0	20	20	0	20	20	0
Phenanthrene ¹	88	59	(33)	120	35	(71)	110	55	(50)
Anthracene ¹	20	20	0	27	20	(26)	20	20	0
Fluoranthene ¹	93	74	(20)	250	83	(67)	130	140	7
Pyrene ¹	60	51	(15)	160	64	(60)	90	85	(6)
Benzo(a)anthracene ¹	51	44	(14)	120	54	(55)	85	61	(28)
Chrysene ¹	85	87	2	230	56	(76)	170	80	(53)
Benzo(b)fluoranthene ¹	47	45	(4)	110	86	(22)	67	110	39
Benzo(k)fluoranthene ¹	20	20	0	33	25	(24)	23	30	23
Benzo(a)pyrene ²	40	40	0	40	40	0	40	40	0
Indeno(1,2,3-c,d)pyrene ²	40	40	0	40	40	0	40	40	0
Dibenzo(a,h)anthracene ²	40	40	0	40	40	0	40	40	0
Benzo(g,h,i)perylene ²	40	40	0	40	40	0	40	40	0

1: Concentrations listed as '20' were flagged with "no measurable response". Concentrations listed as less than 100 were flagged with "a measurable trace amount".

2: Concentrations listed as '40' were flagged with "no measurable response".

In Tables 1 and 2, data are highlighted in bold text if a concentration exceeded the *O. Reg. 153/04* Table 1 background-based concentration. If concentrations exceeded the *O. Reg. 153/04* Table 3 health-based criteria the data are bolded and underlined.

Discussion

Confirmation that there are PAHs in the air is drawn from the Norway maple foliage data. There are no legislated criteria for these compounds in vegetation, nor are there published background data other than in MOE Phytotoxicology reports that address other PAH sources. These limited reports indicate that background concentrations of PAHs in vegetation are at or below the MOE LSB method detection limit. Consequently, it can be said that detection of PAHs in vegetation samples is evidence that a nearby source exists.

Table 3 reveals detectable concentrations at all three foliage sampling locations. The PAHs that were detected appear to be primarily the mid-molecular weight PAHs. The sequence in which the PAH compounds are listed in the preceding data tables is from the low molecular weight, two-ring naphthalene, to the five-ring higher molecular weight compounds. It also appears that foliage at Site 2 is exposed to higher air concentrations of these compounds,

followed by Site 3 and then by Site 1.

As was mentioned previously, the only legislated air standard in Ontario for PAHs is for benzo(a)pyrene and this standard is exceeded regularly in the vicinity of Algoma Steel. The air sampling station is actually farther from the coke ovens than the trees that were sampled. This suggests that tree foliage is not a particularly sensitive environmental receptor by which to monitor air borne PAHs. Nevertheless, PAHs were detected in the foliage, confirming the air quality data.

The opportunity to sample vegetation before and after a rain event was fortuitous, providing a means to evaluate the usefulness of foliage as a PAH monitor. The before and after data clearly indicates apparent losses of PAHs from the foliage by the action of the rainfall. The tree foliage from Site 2 had the highest pre-rain concentrations and lost the most. The other trees generally lost PAHs as well but the analytical data suggest that some PAH compounds were present in elevated concentrations even after the rain. Intuitively, one would expect that PAHs adhering to air borne dust particles would be intercepted by the foliage and that rain would wash some of the particles, and therefore the PAHs, off the foliage. What this exercise does show is that precipitation can alter the PAH containing dust that impinges on foliage during the preceding dry period.

The soil PAH concentration data in Table 1 for Sites 21 through 40 are in excellent agreement with data for samples from the same locations collected in 2002. The concentrations are above background, as defined in Table 1 of *O. Reg. 153/04*. For these first 20 sample sites, there were no cases where health-based standards were exceeded. By extending the number of sampling locations by ten, the same could be said about nine of these sites. The only unique observation from the 2005 sampling was Site 47, where concentrations of PAHs were noticeably higher and the only case where the Table 3 *O. Reg. 153/04* health-based standard of 1,200 nanograms per gram of benzo(a)pyrene was exceeded, although marginally.

The final process in this investigation was an attempt to reconcile the elevated concentrations in the air, confirmed with foliage data, with a lack of more frequent occurrences of significantly elevated soil PAH concentrations. This was even more of a curiosity given the many decades during which the coke ovens have operated and during times when emission controls were not as efficient. Generally, emissions fall out in relative proximity to the source and if emissions are significant and soil conditions don't favour losses through leaching, with time contaminants often accumulate in surface soil.

The three locations within the residential neighbourhood where the soil was sampled in five centimetre increments to a depth of 20 centimetres (Table 2) revealed elevated PAH concentrations throughout the soil profile. With only one minor exception, the concentrations of all PAH compounds in the top five centimetres of soil were higher than in the 15 to 20 centimetre layer. This is a clear indicator of deposition from the atmosphere.

At Sites 21 and 32 there is a clear trend of decreasing PAH concentrations with increasing depth. Site 25 does not follow this trend. Here the highest concentrations were in the five to ten centimetre increment. Trying to reconcile every variation from a general trend is not always possible without a detailed history of the site that was sampled. A potential suggestion regarding Site 25 is that a simple activity, such as re-sodding a lawn, adds a thin layer of cleaner soil on top of the contaminated surface soil, which then becomes part of the sample that is collected.

More importantly, the data derived by sampling three sites in depth increments provides a possible explanation as to why surface soil PAH concentrations are not higher in this neighbourhood. The evidence suggests that the long-term deposition of PAHs from the Algoma coke ovens has had sufficient time to migrate into subsurface soil. The soil in this area is sandy, providing ideal conditions for small particles with adsorbed PAHs to find a path between soil grains and migrate downwards with soil water. Unlike metal contamination where elemental valences can react with the soil minerals and soil organic matter and bind the contaminant to the upper soil layers, the particulates carrying PAHs could simply migrate down with gravity through the sandy soil with each rainfall or snow melt.

As mentioned previously, the purpose in sampling the fourth location, Site 20, in increments was to reconcile the unusually high surface soil PAH concentrations when it was first sampled in 1998. Site 20 in Table 2 has soil PAH concentrations that exceed *O. Reg. 153/04* Table 1 background soil standards for most PAHs and the *O. Reg. 153/04* Table 3 health-based standard for benzo(a)pyrene in all depth increments.

Site 20, located in a park-like setting near the entrance to the ship canal, was probably created during canal reconstruction. The soil at this location is unlikely to be indigenous and probably consists of fill brought in during the reconstruction. Since this location is accessible to the public and has a park-like landuse, and soil PAH concentrations exceed the effects-based soil standards, additional investigation is warranted to further explore the extent of possible soil PAH contamination in this area.

Conclusions

The data provided by sampling Norway maple foliage at three locations confirmed that there is an ambient air PAH source in the vicinity. Re-sampling the foliage the day after a significant rainfall resulted in measurably lower foliar PAH levels, indicated that PAHs are likely associated with dust particles and rain can effectively remove dust, lowering foliar contaminant levels. Foliar sampling can indicate whether there is a local PAH source, but the effectiveness of year-on-year investigations to evaluate trends over time should take into account the length of time between rain events prior to sampling.

This investigation confirmed what was determined in 2002, namely that surface soil PAH concentrations in the residential neighbourhood adjacent to the northwest of Algoma Steel were higher than background, and at one location sampled in 2005 the surface soil concentration of benzo(a)pyrene exceeded the Table 3 *O. Reg. 153/04* effects-based soil standard.

This investigation provided insight regarding the fate of PAHs emitted from the Algoma Steel coke ovens over many decades. It is likely the sandy soil conditions were conducive to migration of particulates containing PAHs down through the soil profile.

The extent of soil PAH contamination in the vicinity of sample site 20 warrants further investigation. The elevated soil PAH levels at this site are likely associated with contaminated fill used for the reconstruction of the canal.

APPENDIX A

Ontario Regulation 153/04 Soil, Ground Water, and Sediment Standards

The Ministry's soil, ground water, and sediment standards are for use under *Part XV.I* of the *Environmental Protection Act* and are referred to in the *Record of Site Condition Ontario Regulation 153/04*. In 1996 the Ministry published the *Guideline for Use at Contaminated Sites in Ontario*, which provided industrial property owners and their consultants with guidance in identifying and cleaning up contaminated soil on their property. As of October 1, 2004 the site assessment and remediation of properties for which a Record of Site Condition is filed will need to conform to the requirements set out in *O. Reg 153/04*.

The standards set out in *O. Reg 153/04* were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect to human health or the natural environment. In setting the *O. Reg 153/04* standards, the Ministry reviewed the international literature and Ontario environmental data and determined the lowest concentration that may cause an adverse effect to the natural environment and the lowest concentration that may have an adverse human health effect and set the standard at whichever value was lower. By setting the standard to protect the most sensitive environmental receptor all other biological receptors, both human and the natural environment, should be protected by default. In cases where the criteria to protect human health or the natural environment are lower than natural background levels, then the *O. Reg 153/04* standard is set at background. The development of these standards is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in modifications to the existing standards.

O. Reg. 153/04 standards are not action levels, in that an exceedence does not automatically mean that a clean-up must be conducted. The criteria were prepared to help industrial property owners clean-up contamination on their property when the land is intended to be sold, the zoning changed, and/or the property redeveloped to a more sensitive land-use. For example, the owner of an industrial property that plans to sell the land to a developer to build residential housing must meet the criteria set out in *O. Reg. 153/04* in order to obtain a Record of Site Condition, which is an acknowledgement by the Ministry that they have met Ministry environmental standards. In this way previously-contaminated industrial land can be safely re-developed for residential or parkland use without concern for adverse environmental or human health effects. In addition, most municipalities insist that contaminated land is cleaned up according to *O. Reg 153/04* before they will approve a zoning change, therefore industrial property owners and developers are obliged to comply with the Regulation.

O. Reg. 153/04 contains a series of Tables (1 through 6), each having criteria for soil, sediment, and ground water for various land-use categories (eg, agricultural, residential, industrial). *Table 1* criteria reflect the upper range of background concentrations in Ontario. An exceedence of *Table 1* indicates the likely presence of a contaminant source. *Tables 2 through 5* criteria are effects-based and relate to potable or non-potable ground water conditions. The criteria in *Tables 2 through 5* take into consideration the potential for adverse effects from exposure to contaminated media through ingestion and direct contact, through contaminant transfer from soil

to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, and from ground water discharge to surface water. However, the criteria **may not** ensure that corrosive, explosive, or unstable soil conditions will be eliminated. *Table 6* is used to determine if the property qualifies as a “shallow soil” property, which places additional restrictions on the site under Section 41 of *O. Reg 153/04*.

Although written specifically to assist industrial landowners in the sale and redevelopment of their own contaminated site, the environmental standards in *O. Reg. 153/04* are becoming used more widely to interpret soil, sediment, and ground water quality at the community or even the landscape scale. When used in this manner, an exceedence of the *O. Reg 153/04* criteria do not imply that remediation is required, rather it suggests that additional studies are warranted. These additional studies may involve more environmental sampling, an ecological or a human health risk assessment, or even a health study. Decisions on the need to undertake any additional studies when the criteria in *O. Reg. 153/04* are exceeded are made on a site by site basis and are usually contingent on the contaminants having the demonstrated likelihood to cause an adverse effect to the natural environment or human health.

Because of society’s long industrial history and our practice of living close to our work place the soil in many communities in Ontario may be contaminated above the effects-based criteria in *O. Reg 153/04*. In practice, remediation of contaminated soil on privately-owned residential property and public green spaces has only been conducted in communities when the potential for adverse health effects has been demonstrated.

For more information on the rationale for the Ministry’s soil, sediment, and ground water criteria in *O. Reg 153/04* please refer to the *Rationale for the Development and Application of Generic Soil, Ground Water and Sediment Criteria for Use at Contaminated Sites in Ontario (December 1996)*.